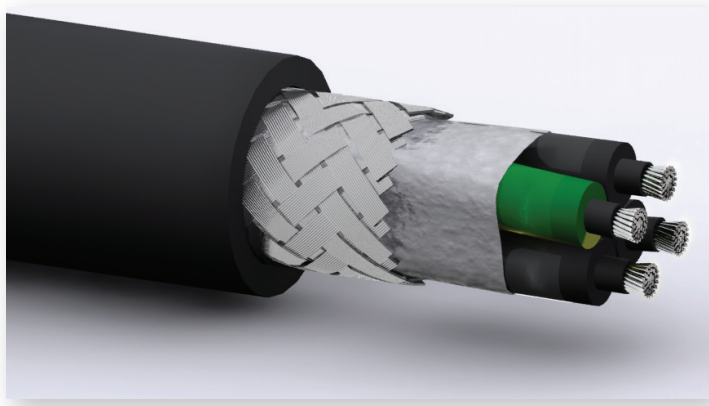


SELECTING CABLES FOR VFD APPLICATIONS

Review four cable design factors to maximize reliability in drive applications

By **John Gavilanes**, *Director of Engineering*



For all their energy savings and process control benefits, variable frequency drive (VFD) systems have a downside too. When these drives fail, they can bring motor-driven industrial processes to a dead stop. To avoid this costly downtime, smart engineers carefully evaluate reliability when configuring a drive system.

All too often, however, the reliability analysis focuses solely on the VFD power electronics and neglects the most vulnerable component in the drive system—the power cable that connects the VFD to the motor.

The truth is, however, that power electronics have already become very reliable over the years. By design, they can handle the typical voltage spikes, inrush currents, harmonics and other power distortions that arise during VFD operation. Their controls can also prevent damaging electrical conditions or shut down the drive altogether if power distortions rise to unsafe levels.

Cables do not have any such protection and can fail if subjected to electrical conditions that generate more heat or voltage levels than the cable's insulating layers can tolerate. Cables in industrial settings may also experience mechanical loads and chemical exposures that lead to damage and premature failure.

Fortunately, it is possible to avoid VFD-related cable failures and the associated downtime by paying attention to a few cable construction details. The overall performance of the drive system will also improve in many cases. Here's what to look for:

THE RIGHT MATERIALS

Not all insulation and jacketing materials are created equal when it comes to electrical performance. So it's important to match cable materials to specific VFD application requirements.

Even medium power VFD applications, for example, run the risk of damage from voltage spikes or other power distortions (See "The Problem With Cables" sidebar). In these cases, consider VFD cables that make use of semiconductive layers between the conductors and the primary insulation. Semiconductive insulation systems have for decades been employed in the high voltage cables used for power distribution. More recently, they have been applied to VFD cables to protect against electrical damage.

Semiconductive insulation works by alleviating corona discharge and high points of electrical stress in primary insulation. The result is greatly improved cable reliability, extended life and an increase in dielectric strength properties. Our testing under the ICEA T-24-380 standard shows that when compared to other insulative systems corona inception and extinction levels improved significantly when semi conductive compounds were used.

Another VFD application challenge involves long cable runs, which are increasingly common in modern manufacturing facilities. Because capacitance loads increase with length, these long cable runs have an increased risk of overload conditions that can trigger the VFD's protective systems.

The use of cables with the crosslinked polyethylene (XLPE) insulation can minimize this risk.

XLPE insulation has a relatively lower dielectric constant that reduces the capacitive effect in long cable runs. XLPE also has excellent thermo-mechanical properties that allow the XLPE insulation to withstand the heat generated by overcurrent conditions.

VFD applications requiring high precision control impose yet other requirements on the cable. Though it may not be obvious, the cable's insulation can actually influence the control response of the drive. An appropriate insulation system, will minimize transfer impedance and improve the velocity of propagation to produce a more efficient control response.

MECHANICAL PERFORMANCE

With VFDs typically installed in factory environments, cables must be engineered to withstand mechanical abuse and environmental exposures. Some of the key mechanical attributes in VFD installations include:

- **Flexibility.** Enhanced flexibility pays off throughout the cable's life cycle. During installation, flexibility makes handling and routing easier. In use, flexible cables are less susceptible to damage from bending. Stress free cables, created by removing the back twist from cables, is one way to improve flexibility and is an important feature to look for when in tight bend radius installations.
- **Oil Resistance.** For industrial applications where oil exposure is a concern, make sure that you select cables with a PVC jacket that has been specially formulated for oil resistance. Cables that comply with Underwriters Laboratories' stringent oil resistance standards can be surface marked as Oil Resistant I or Oil Resistant II.
- **Crush Tested.** Consider whether cables have the crush resistance needed for the installation. Cables certified as TC-ER, for both tray and exposed run installation, have to pass rigorous mechanical tests for cable crush and impact resistance, including UL Standard 1569. Because these rugged cables need no conduit, they can significantly drive down installation time and cost.

LAPP VFD ADVANTAGES

Products		
ÖLFLEX® VFD XL	ÖLFLEX® VFD Slim	VFD Generic Type B
.045 XLPE	Surge Guard	.045 XLPE
Jackets		
Specially formulated PVC	Specially formulated PVC	PVC

Properties	Ratings			Comments
DC Resistance (ohms/1000 ft.)	1	1	2	#1 - Stranding meets UL & VDE
Voltage Drop (volts)	1	1	2	#1 - Lowest voltage drop
Longer Lengths (feet)	1	1	2	#1 - Longest lengths
Ampacity (amperes)	1	1	2	#1 - Highest ampacity
Corona Testing (voltage)	2	1	2	#1 - Highest inception/extinction
Capacitance (conductor – conductor)	1	2	1	#1 - Lowest capacitance
Impedance (ohms)	1	2	1	#1 - Higher impedance
Inductance (henrys)	1	2	1	#1 - Higher impedance
Oil (aging)	1	1	3	#1 - Meets Oil Res II
Low Temperature (degrees Celsius)	1	1	3	#1 - Meets -25°C cold impact
Flexibility (durometer)	1	1	3	#1 - Highly flexible
Mechanical (pound-force)	1	1	3	#1 - Crush/impact force
Shield Effectiveness (decibels)	1	1	2	AMA tape vs. AM tape
1 = Best 2 = Average 3 = Fair				

Voltage Drop Comparison

Cable Sample	AWG Stranding	Circular Mil Area	DCR (ohms/1000 ft.)	Current (amperes)	Calculation: DCR x Current	Voltage Drop (volts)
ÖLFLEX® VFD XL	12; Class 5	7665	1.36	5	1.36 x 5 =	6.8
VFD Generic Type B	12; 65/30	6500	1.72	5	1.75 x 5 =	8.6

Lapp's ÖLFLEX® VFD XL exhibits approximately 25% less DC resistance than the VFD generic type B product. This substantial difference precipitates a significant decrease in voltage drop, a higher current carrying capability, and the option of accommodating applications that require longer cable lengths. More copper means less resistance which results in less heat generated.

PROPER SHIELDING

Because VFDs can be susceptible to electrical noise, particularly in process control applications, it's important to pay attention to the shielding methods used in both the cable itself and any connectors.

The most effective type of shielding combines a triple-laminate foil tape and 85% braid coverage. This eliminates two types of noise problems: 1) it prevents externally generated noise from entering and causing internal signal disruptions, 2) and it also prevents noise generated from within the cable itself from exiting, which could cause unintended disruption to nearby electronic equipment.

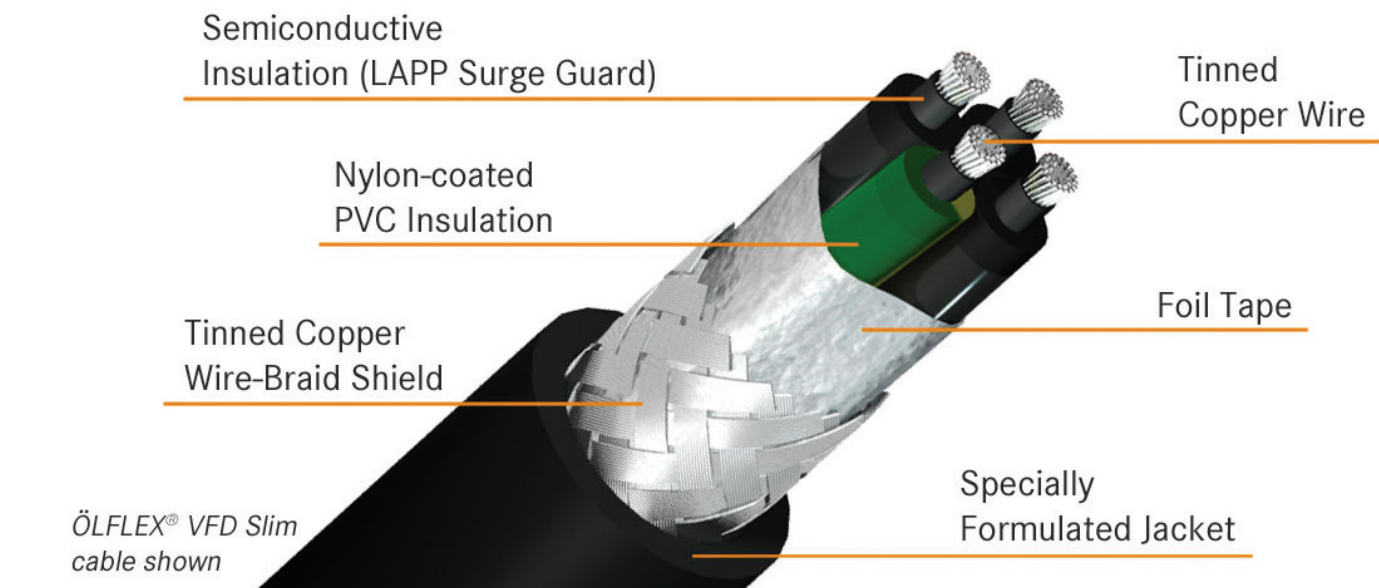
As for the connectors, they need to be well shielded too. Look for those which provide full shield grounding, low transfer impedance from the shield to conduit entry plates, and 360° of termination. Connectors with these features are referenced in Section 4-5 of Rockwell Automation's Wiring and Grounding Guidelines for Pulse Width Modulated AC Drives.

OPTIMIZED STRANDING

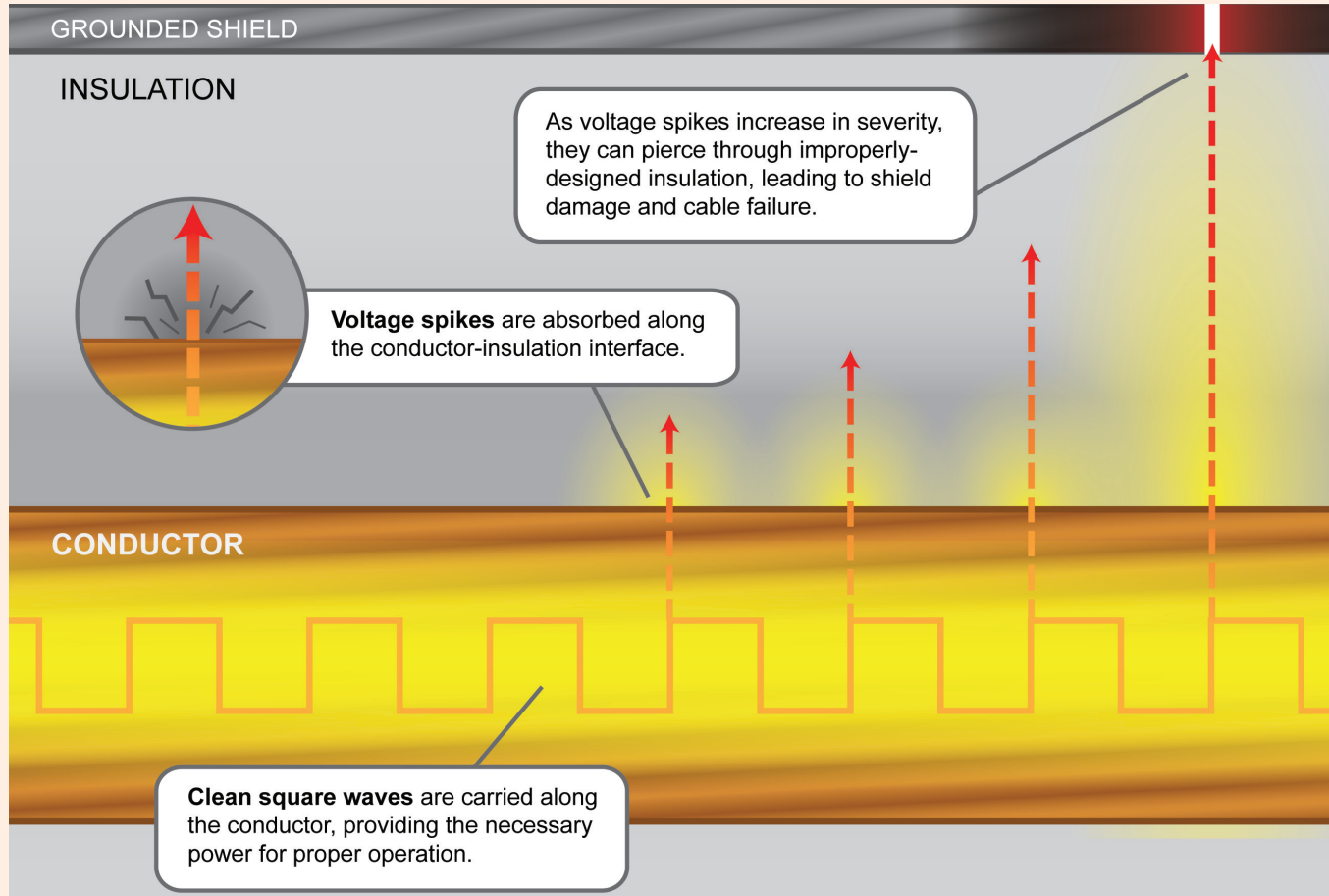
Cables stranding designs, which can vary substantially, also play a role in the efficiency of a drive system. One often neglected consideration involves the cable's circular mil area, or CMA. Cables whose conductors have a large CMA have lower DC resistance than cables with a smaller CMA. Low DC resistance, in turn, translates to significantly lower voltage drop across a given length of wire.

CONCLUSION

With VFDs now firmly established in manufacturing settings, their uptime matters more than ever. Engineers, however, often forget to consider the contribution that power cables make to the overall reliability and performance of the VFD system. Choosing cables whose materials, mechanical performance, shielding and stranding are designed for electrical and environmental stresses of a VFD application is one of the simplest ways to keep that drive up and running.



THE PROBLEM WITH CABLE



In VFD operations, the inversion voltage normally rises from zero to 650 volts then back to zero approximately 20,000 times per second. During these fluctuations, the nominal voltage can overshoot from 650 volts to 2,000 volts or more. Even though these voltage spikes last for only millionths of a second, they can permanently damage or even destroy an improperly designed cable.

Voltage spikes do their damage when they puncture the cable insulation, which allows the current to travel into the braid shield.

The current can generate enough heat to burn a hole in the braid. When the hole grows large enough, the cable insulation will self-heal, leaving lasting damage to the braid. This process will repeat at different locations along the length of the cable until total failure has occurred, leading to production downtime.

It's worth noting that longer lengths of power supply cable will experience voltage spikes more frequently and more intensely than shorter lengths.

LAPP GROUP PRODUCTS

Product Name	Description	UL / CSA Approvals	UL Oil Res I	UL Oil Res II	-25°C Impact	-40°C Bend	FT4 Flame
ÖLFLEX® VFD XL	Power & Control Tray Cable	600V – TC WTTTC 1000V & CIC/TC	X	X	X	X	X
ÖLFLEX® VFD Slim	Power VFD Cable	600V – TC WTTTC 1000V & CIC/TC	X	X	X	X	X
ÖLFLEX® VFD Symmetrical	Power VFD Cable with Symmetrical Grounds	600V – TC WTTTC 1000V & CIC/TC	X	X	X	X	X
ÖLFLEX® VFD	Power VFD Cable with Inner Jacket	Bus Drop & MTW 600V	X	X	X	X	X
ÖLFLEX® VFD with Brake	Power VFD Cable with 1 Pair for Brake	600V – TC WTTTC 1000V & CIC/TC	X	X	X	X	X
ÖLFLEX® FD VFD	Power VFD Cable for Continuous Flex	600V – TC WTTTC 1000V & CIC/TC	X	X	X	X	X
ÖLFLEX® SERVO 2YSLCY-JB	Flexible European VFD Power Cable	1000V – CE	X				

To provide the most effectiveness, the use of Lapp SKINTOP® MS-SC/MS-SCL or MS-SC-M BRUSH/BRUSH PLUS is recommended to achieve full 360° shield ground termination.